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MODERN

INDUSTRIAL PROGRESS,

AND THE

INFLUENCES ACCELERATING ITS MARCH:

AN ADDRESS DELIVERED AT THE OPENING OF THE FORTY-FIRST ANNUAL EXHIBITION OF THE AMERICAN INSTITUTE OF THE CITY OF NEW YORK;

BY

FREDERICK A. P. BARNARD, LL.D., L.H.D.,

President of Columbia College, and President of the Institute.

New York:
CHARLES H. JONES & CO., PRINTERS,
114 FULTON STREET.
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ADDRESS.

LADIES AND GENTLEMEN:

It is my pleasant duty to bid you welcome to the forty-first annual exhibition of the processes and products of American industry, made under the auspices of the AMERICAN INSTITUTE of New York. Among the goodly company before me are not a few who have honored us with their presence on similar occasions before. These, when they shall presently have had an opportunity to scan with attention the many interesting objects brought together so closely and arranged so tastefully and judiciously in this vast hall, will bear me out, I am sure, in the assertion that in point of variety, in point of value, in point of the beauty and finish of objects of art or articles of manufacture, and in point of the ingenuity displayed in the construction of machines and the efficiency exhibited in their performance under our eyes, the present exhibi-

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tion is decidedly superior to all that have gone before it. There are some in this audience whose opportunities of observation and comparison extend over a long period of years. Here and there, indeed, I observe a veteran devotee to the cause of industrial improvement, who has faithfully labored in promoting the objects and furthering the operations of this INSTITUTE from the day of its foundation, and who has attended every one of its exhibitions from the very first. To such, the contrast which must present itself between that modest beginning, as it returns to the eye of the mind, and the present magnificent display, will seem almost a transformation wrought by the power of magic. This transformation is seen not merely in the greater magnitude of the present exhibition, though in this respect the present surpasses the former in the proportion of twenty, perhaps, to one, but still more in the character of the objects exhibited. For of these objects, many—so many that, if the number were definitely stated, it would excite astonishment if not incredulity—are the products or the instruments of industries which did not exist when this INSTITUTE was founded, and which, in many instances had not yet even suggested themselves to the active brains which have since conceived and perfected them.

INDUSTRIAL CHARACTERISTIC OF THE AGE.

This is a point on which I purpose for a moment to dwell, for it suggests a characteristic which distinctly and strongly marks our age, and sets it in bold and significant

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contrast with all the ages which have gone before; precisely as this illustration of it in our exhibition of to-day is in contrast with that early and feeble demonstration made by our infant INSTITUTE in the year 1830. This characteristic is the extraordinary multiplication of industries and of helps to industry which is going on at this moment, and which has been going on since this century began with a rapidity of movement which increases from year to year in geometrical ratio. An exact measure of this progress it might be difficult to find; still, it is probably safe to say that, taking into consideration the birth of new arts and the increased efficiency introduced into old ones by means of new machines and new processes, the productive power of manufacturing industry has much more than doubled since this INSTITUTE was founded, and has increased ten fold since the declaration of American Independence. It is a fact which we find it difficult to realize at present, but which is nevertheless literally true, that within this brief period, the industry of Europe and America, in all its departments, has been completely revolutionized and transformed, by the substitution of machine labor for hand labor; so that all the numerous, endlessly varied, and wonderfully ingenious forms of mechanism, by means of which the operations of manufacture are at present conducted, have been created out of nothing since the UNITED STATES became a member of the family of nations; simple tools for hand use, and a few machines of the most elementary description, being all that the ingenuity of preceding ages had been able to

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contribute to the advancement of productive power in the useful arts.

RELATION OF THE INDUSTRIAL ARTS TO CIVILIZATION.

In view of this remarkable fact, we are naturally led to inquire how it has happened that the inventive power of man, after the lapse of centuries of slumberous inactivity, should, just at this period of the world's history, have received so sudden an impulse, and have awakened to an activity so lively and so persistent? The arts which minister to human comfort or enjoyment are sometimes spoken of as the arts of civilization. Has our civilization kept step with the march of our industrial improvement? The assumption is often made that we may read the condition of any people as to the degree of its advancement in civilization by simply looking at the products of its industry. In accordance with this principle, Mr. MICHAEL CHEVALIER, Senator of France under the Second Empire, speaking of the picture presented in the great International Exposition of 1862, in London, where were to be seen side by side the exquisitely finished achievements of European skill, and the ruder fabrics of Asiatic, African, or South American industry, remarked that the exhibition formed a perfect map of civilization, in which the relative advancement of all the nations of the earth could be read at a glance. There is something of truth in this, but certainly it is not wholly true. Civilization has possibly reached a higher

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plane to-day, in this country and in England, than it had attained in the year 1772; but certainly the difference is not such a difference as is found to exist between the condition of the industrial arts in either of these countries, at the former of the two periods compared and at the present.

HIGH CIVILIZATION COMPATIBLE WITH A LOW STATE OF INDUSTRY.

If we measure the civilization of a people by the degree of its intellectual culture or its æsthetic refinement, there have been periods in the world's history distinguished for a civilization of the very highest order, when yet the common arts of life were at a low ebb. Such was the culminating period of Grecian literary glory, marked by the production of masterpieces in philosophy, in oratory, in history and in poetry, which for more than two thousand years have commanded the admiration of the world, and which are even yet unsurpassed for power of thought or brilliancy of fancy. Such also was, a few centuries later, the Augustan age of Roman literature, an age which has left behind it monuments of genius hardly less admirable than those of Greece. During both these periods the fine arts also were cultivated to a degree of perfection which the world had never seen before and has scarcely seen since. It is indeed a faith held by many that the sculptures of Praxiteles and Phidias have never been approached in

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merit by any modern production. Yet, at the very time that Athens was thus deluged as it were in a blaze of intellectual light, she had not so much as a water-wheel or a wind-mill in all her territory. Her citizens ground their wheat to flour in a species of wretched hand-mills; employing for this purpose, as for every other toilsome service, the labor of slaves. The industrial arts were, in fact, very unequally developed among the Greeks. None attained a higher degree of perfection among that people than the absolute necessities of the civilized state demanded; unless they happened to be arts capable of feeding the love of splendor, as well as of ministering to the natural wants of man. Thus architecture was cultivated and exalted to the rank of a fine art; and the crumbling monuments of that early architectural period are still studied for their beautiful proportions; while the principles of construction laid down by their builders continue to be received as law by the architects of our own time. In respect to most other arts, however, the polished Greeks were far behind such peoples as at this day we are accustomed to speak of contemptuously as half civilized. They had learned the composition of glass, and for some simple purposes they had made use of it: but they knew nothing of the use of lenses for the assistance of imperfect vision, nor did their ingenuity suffice to the invention of a simple plane mirror to furnish the dressing-rooms of their ladies. They constructed wheeled vehicles for chariots in war, and for the transportation of persons and merchandise in peace; but they had not the sagacity

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to suspend the bodies of these vehicles, and they were consequently driven to the employment of chairs or litters borne by slaves, for conveyance with any degree of comfort from place to place. The implements of their agriculture were no less rude. In its ordinary form, the Greek or Roman plow was little better than a crooked stick sharpened; and even in its most elaborate construction, as described by VIRGIL, it was ridiculously inadequate to the object intended. Nor was the condition of their carpentry any better. They possessed no implements corresponding to the modern plane; but shaped and smoothed their planks and timbers as they best could with the saw, the chisel and the adze.

THE EGYPTIAN CIVILIZATION.

But the Greeks were by no means the earliest of peoples to attain an advanced civilization, without apparently any corresponding development of the common arts of life. Judging by the magnitude and the artistic character of the architectural monuments which they left behind them in the valley of the Nile, the ancient Egyptians must have attained a very high degree of culture at a period vastly more ancient. Among these monuments, the earliest in date of all is ascertained to be the pyramid of CHEOPS, a stupendous mass of masonry covering an area of thirteen acres in extent, and in its originally perfect state rising to an altitude greater than has ever been given to any other artificial structure erected by man.

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The point of time in ancient chronology to which this great monument should be assigned is matter of dispute. Some authorities carry it back more than five thousand years before the Christian era, but none bring it nearer to us than the two thousand seven hundredth year before Christ, which would place it some four thousand six hundred years before our own time. In the many centuries of darkness and violence which have elapsed since the early civilization of Egypt was blotted out, this magnificent structure has been despoiled, through the reckless cupidity of barbarian conquerors, of its once beautiful external sheathing; so that it presents now to the eye of the traveler the aspect of a rude pile of roughly shapen stones. Yet still its internal passages and chambers, protected by their difficult accessibility, exhibit all the perfection and finish which once characterized the whole; and which is such as to have drawn from expert engineers and men of science, who have made its details a study, the extraordinary testimony that this, the most ancient architectural structure in all the world, is, in its workmanship, also the most perfect. And notwithstanding this, there is no evidence that the Egyptians were any more advanced than the Greeks in the arts which we call distinctively useful.

CAUSES ACCELERATING THE PROGRESS OF MODERN INDUSTRY.

These references to the evidences of a high state of civilization existing along with a meagre development of

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the common arts of life in remote antiquity, are designed to show that the giant growth of the productive power of industry in the latest of the centuries, is by no means to be accounted for on the assumption of the superior civilization of our own times. The causes must, therefore, be sought elsewhere; and in this instance as in regard to many other social phenomena, they will be found in a combination of influences which, though the silent growth of centuries, have only begun to operate harmoniously and powerfully in these recent years. Among these influences two have been prëeminently efficient, and these I propose briefly to notice. First, as especially honorable to our age, I name the recognition in modern society of the dignity of labor. The other is the stimulating influence of scientific investigation upon industrial improvement.

MODERN RECOGNITION OF THE DIGNITY OF LABOR.

In those early periods of high civilization to which reference has been made, the task of providing for the daily wants of society was laid upon a servile class; and if any freeman felt himself compelled by the narrowness of his means to engage in a mechanical occupation, he was esteemed as little better than a slave. Society was thus divided into castes. To the superior class belonged all the culture and refinement; to the inferior all the toil. The processes of the arts of industry were followed by those who were fated to pursue them, in a dull and

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spiritless routine. The operative felt no pride in his calling, and no ambition to improve its methods. There was no stimulus to such an ambition, since improvement could bring with it no honor; and whatever aspirations might arise in the breast of an individual of humble rank to mend his position, incited rather the desire to escape from his vocation than to attain excellence in it. If the statesmanship of those times was sagacious enough, as it probably was, to perceive that the wealth of a nation, and by consequence its political importance and its military strength, depend upon the productiveness of its industry, it was nevertheless blind to the truth that in order that industry may be productive, labor must be made honorable.

Upon this point we at length see clearly. Intellectual culture is prized by us no less highly than it was among the Greeks—more highly, perhaps, in a certain sense, since we desire that its benefits shall be extended to the multitudes, and not confined to a few; but we have discovered that culture and practical usefulness are not at variance, and that both in their several ways are deserving of respect. That may be a high state of civilization, but it certainly is not a healthy or desirable one, in which an aristocracy of wealth or of family monopolizes the intelligence and the refinement and the political power, while the great mass of the people, crushed beneath the weight of poverty and ignorance, are forced to minister to the wants, the comforts and the pleasures of their superiors, and are despised because they do so. Such a civilization

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observed across an intervening waste of barbarous centuries, may seem all beautiful and bright, because its repulsive features are obscured by distance, while the more brilliant remain conspicuous; but it exists in violation at once of equity and of the common interests of all the classes whom it covers; and, resting on no solid ground, is liable always to be swept away by convulsions originating among its own unstable social elements, or by violence proceeding from without.

MODERN AND ANCIENT CIVILIZATION CONTRASTED.

The civilization of the century in which we live is something widely different from this. Its tendency is to the intellectual and moral elevation, not of a favored few, but of the whole people. Yet recognizing the undeniable truth that before the mind can be cultivated or improved, the body must be provided for, it encourages and recompenses with honor every honest effort to ameliorate the physical condition of the race. It accordingly esteems the man who succeeds in making two blades of grass grow where one grew before as a greater benefactor of his countrymen, than the general who wins a battle or the conqueror who subdues an empire. And extending this principle, it bestows the same honorable commendation upon every one who contrives by whatever instrumentality to produce in increased abundance any article

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capable of contributing to the sustenance or the comfort of man, and of thus promoting the general welfare.

Under the influence of such a civilization, the power of invention is naturally stimulated to a high degree of activity. And accordingly, our age is the age of the inventor's triumphs. This truth becomes strikingly manifest when we consider how many names there are of men now living or of men who have been living within the last one hundred years, which are destined to be held forever in grateful remembrance for their contributions to the improvement of the useful arts; and how brief is the list of similar benefactors of mankind which can be gathered from the history of all the preceding centuries. WATT, ARKWRIGHT, ROBERTS, JACQUARD, WHITNEY, WEDGWOOD, FULTON, STEVENSON, FOURDRINIER, HOWE, MCCORMICK, WHITWORTH, SIEMENS, FAIRBAIRN, BESSEMER, APPLEGARTH, HOE, BULLOCK, HIRN, ERICSSON, MORSE, HUGHES—I mentioned but a few to illustrate the readiness with which names rise to the lips; while if we go back beyond the middle of the eighteenth century we find but here and there a scattering example, such as GUTENBERG, PALISSY, or HUNTSMAN; and earlier than the fifteenth we find none at all.

The recognition of the dignity of labor, so distinctive of our time, has been the result of no sudden change in the mutual relations of the different classes of society. Revolutions in matters of sentiment are never sudden, but always involve and often largely involve the element of time. This is even true in matters of mere opinion; for

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though individuals may be found impressible by argument, or may spontaneously abandon erroneous views, the instance is not on record in which a whole community has become convinced of error in a day. Prejudices are laid aside with much greater difficulty than opinions. It is probable that the prejudices of a people are never in a proper sense eradicated. They die out, if they disappear at all, in measure as the individuals who entertain them pass away, and give place to others who are less strongly biased.

INDUSTRY DURING THE MIDDLE AGES.

During the middle ages, in Europe, the state of industry was materially superior to that which prevailed under the Roman Empire. Certain changes, chiefly social, but to some extent political, crept in during this later period, by which the condition of the industrial classes was affected, in some respects favorably, and in others injuriously, the advantage on the whole being on the favorable side. The several trades became organized into societies for mutual protection and assistance. And their growing prosperity suggested to monarchs and their ministers of finance the expediency of lending them encouragement by way of strengthening the revenues of the State. Thus in France, under Louis XIV., the organized trades, or *communes*, were admitted to the enjoyment of certain political privileges under the name of "the third estate." In other parts of Europe, as in Holland, in Upper and Middle Italy, and in

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portions of Germany, they attained temporary advantages of still greater importance; but these, through the jealousy as well of monarchs as of feudal chiefs, were soon wrested from them, and they were long subjected to heavy exactions; while the severe regulations by which their freedom was trammeled, repressed almost wholly the spirit of improvement. Even so wise a minister as COLBERT gave his sanction to a system which held society while it lasted as if in a cast-iron mould, making trades hereditary in families from generation to generation, and prohibiting any one from the practice of any art save that to which he was born.

It was, however, a great advance toward the recognition of the dignity of labor, when kings and ministers and barons contended as to the place to be assigned in the political and social system to the organized industries. In this contention the common sense of mankind could not fail to enlist itself more and more on the side of liberality; still, complete emancipation from the artificial shackles by which the freedom of industry was trammeled was never obtained, up to the time when the outbursting storm of the first French revolution subverted the foundation of the whole social system of continental Europe, and "liberty, equality, and fraternity" became the watchwords of the hour. Then, in the chaos that succeeded, old things passed away and all things became new. When at length the troubled elements became again composed, industry, respected in the persons of its representatives, and freed from most of the embarrassments which had impeded its

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development before, entered upon that career of wonderful expansion of which the accumulated results astonish us to-day.

INFLUENCE OF SCIENCE UPON INDUSTRIAL IMPROVEMENT.

I mentioned above, as the second of the important influences accelerating, in our day, the progress of industrial improvement, the stimulating influence of contemporaneous scientific investigation. It is an undeniable fact that nearly every important improvement which has been made during the last one hundred years in the processes or the instrumentalities employed in the industrial arts, has been due directly or indirectly to the suggestions of science. Examples illustrative of this truth are so abundant that, in a great exhibition like the present, we encounter them wherever we look. Nay, it is not necessary to this end to visit a gallery of industry. We see examples all around us, in the public streets and at home in our own dwellings; many of them indeed so familiar that we forget the source to which we owe them. A friction match, for instance, appears to us a very trivial thing; and yet it is a gift of science, and withal a very recent gift, since in the year in which this INSTITUTE was founded, the world had no friction matches. The gas, which is now so almost universally used for the artificial lighting of towns and dwellings, is another gift which science has conferred on industry, and conferred since this century began. And since the subject of illumination has

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presented itself, though chosen entirely at random, there are also to be mentioned stearine and paraffine, the oil expressed from lard, kerosene distilled from petroleum, and finally, and more striking still, the powerful electric lamp adopted by France and England in their first-class sea-coast light-houses, all of these being contributions made in recent years by science to the useful arts.

Take, again, the case of india-rubber. There are many persons here present whose memory extends to the time when this substance, now so valuable, had no higher use than that which gives it its name—to efface pencil-marks on paper. Its present applications are so various as almost to defy enumeration. Among the most familiar of the articles into which it enters may be mentioned water-proof garments, portable beds, cushions, life-preservers, elastic tissues, machine-belts, buffers for railroad cars, foot-mats, floor-coverings; and, in the solidified form, knife and instrument handles, door-knobs, drinking-vessels, writing-desks, jewel-boxes, combs, pen-holders, musical instruments, and a multitude of other articles, for the construction of which it is better adapted than any other material on account of its unalterability by either heat or moisture. For the vast improvements of the present century in the manufacture of paper we are once more deeply indebted to modern science. This is true in too many particulars to admit here of detail, in the preparation of the pulp, in the expeditious processes of bleaching, and in the wonderfully ingenious machinery by which the product is turned out finished, in sheets practically endless.

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Look again at the marvelous fertility in useful applications of the galvanoplastic art—an art presented by science to industry, perfect from the very beginning: and requiring of the ingenuity of inventors only to devise the means of adapting it to different conditions. Galvanoplasty has not only superseded all the old and slow and unhealthy processes of silvering and gilding, the use for which it was first made available as a branch of industry, but it has contributed at some point or other to the advancement of nearly every useful art. Printing and engraving furnish signal examples of its usefulness. It affords a simple and easy means of giving to movable type and to stereotype plates a facing of copper, or, in the later improvements, even of iron; whereby their durability is immensely increased. The service it has rendered to the art of engraving, whether on copper or on wood, is still more noteworthy. Woodcut engravings, when finely finished, are too frail to bear long, without injury, the severe treatment they receive under the letter press. The delicacy of the lines is soon lost, and the impression ceases to do justice to the skill of the artist. By the galvanoplastic process, a copper fac-simile is substituted for the original wood-cut, with the double advantage of furnishing a more durable material and of retaining the power to replace the copy by a new fac-simile when those previously used shall fail. The same expedient is resorted to when the original engraving is on metal. This original is only employed to furnish galvanoplastic duplicates for use in the press; so that when an engraving is once made,

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its durability is practically unlimited. All the large and valuable charts of the American Coast Survey, many of them embodying the results of immense labor, are produced on this plan.

But time will not allow me to multiply illustrations. I will merely name, without pausing to go into details, a few of the departments of industry not above mentioned, to which the contributions made by science have been most signal. There is the metallurgic industry, for instance, which has been profited in all its branches; as the metallurgy of iron, of copper, of zinc, of the precious metals, of aluminium, and most signal of all, of steel. There is the manufacture of sugar, from the cane and from the beet, and the process of its subsequent refinement, the whole of which has been thoroughly revolutionized within the past twenty years. There are the manufacture of leather, the silvering of mirrors, the processes of bleaching and dyeing, the discovery of new dyes, especially of the magnificent colors called aniline, the manufacture of soda ash, the power printing press, machine spinning, weaving, knitting, and sewing, the whole family of machine tools, the manufacture of brick and tiles, the artificial production of ice, the tunneling of mountains by the aid of power-drills and the formidable explosives, dynamite and nitro-glycerine, the whole system of modern transportation by land and sea, and telegraphic communications spanning almost instantaneously the world's circumference and annihilating space. I pause in the enumeration, not for want of

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material, but because it is necessary to pause somewhere. In every one of the branches of industrial art here mentioned, the inventions or discoveries which give them their principal usefulness or productive power have been made since the foundation of our Government, and most of them quite recently.

SCIENCE AND INDUSTRY IN ANCIENT TIMES.

The inquiry naturally arises, why did not science come with her aid to industry at an earlier day? Science is the creation of intellect, and intellect was actively awake in the earliest periods of history, and even in periods to which the light of history does not extend. We have already spoken of Egypt, and of the evidence her monuments furnish of an early advanced civilization. Mind must have been active then. The Egyptians must have been learned, or it would have availed little to MOSES that he was learned in all the wisdom of the Egyptians. They must certainly have cultivated letters. Probably they were not wholly neglectful of science. Unquestionably they must have been geometers and engineers, or they never could have built the pyramids, or raised the obelisks. From a protracted study of the great pyramid of CHEOPS, Admiral SMYTH has satisfied himself that they were also astronomers, and pretty good astronomers too. The Chaldeans and the Greeks of Asia Minor cultivated astronomy also twenty-five hundred years ago; and it is asserted of THALES of

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Miletus that he predicted eclipses in anticipation of their occurence, some centuries before the golden period of Grecian literature. In Alexandria, under the PTOLEMIES, the pure mathematics were cultivated so successfully that the treatises of some Alexandrian mathematicians, as of APPOLLONIUS and EUCLID, are held in respect to this day. EUCLID'S Elements of Geometry still, indeed, maintain a place among the text-books of English and American colleges. During the same period, ERATOSTHENES, an astronomer of Cyrene, made an ingenious attempt to determine the dimensions of the earth by measuring a degree of the meridian; with what success, our ignorance of the value of the unit of length employed by him makes it difficult to judge. This, too, was the age of the illustrious ARCHIMEDES, a physicist who certainly made some signal discoveries the records of which are lost; and who is said, in the history of that time, to have accomplished results by mechanical and optical arrangements, which, even in this age, would be regarded as extraordinary. Thus we see that science, and even the sciences of nature, occupied the minds of men in periods of high antiquity; and we know that, during the same periods, literature attained to its greatest splendor; speculative philosophy especially, a subject demanding the exercise of the loftiest powers of the human intellect, having been cultivated with such success, that the teachers of that time continue still to be studied with profound interest, and made the subject of endless discussion and criticism.

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ANCIENT SCIENCE WAS NOT PROGRESSIVE.

How then happened it that for twenty centuries—if we count from the Egyptian epoch we may even say for fifty—science brought to the useful arts so meagre contributions, while in this last age of ours she comes laden down with gifts every succeeding year? The immediate answer which presents itself is that science herself stood still during all those long centuries. This answer, though obvious enough, is unsatisfactory, since it only removes the difficulty one step further back, and compels us to inquire why science should have been stationary so long, and why she has been less so in later times. For this phenomenon, unaccountable as it seems at first, we find an explanation when we turn our attention to the methods of investigation employed by ancient and modern inquirers respectively in the prosecution of their researches. We find the modern methods to be such as, if faithfully pursued, must in the necessity of things, lead eventually to substantial and trustworthy results. The ancient, on the contrary, are much more likely to bewilder and lead astray, than to conduct to the truth. Such discoveries, therefore, in the sciences of nature, as were made in antiquity, unless in the case of some man of exceptional sagacity, like ARCHIMEDES who seems to have escaped the mental tendencies of his age, were usually accidental; and were hardly ever the legitimate rewards of direct inquiry. It is worth while to explain the difference.

Modern investigation then begins with simple facts, and takes exact note of what the facts are. It assumes

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that these facts exist in obedience to some law, at present unknown, which makes their existence necessary. And it assumes that if we multiply observations of analogous facts under varying conditions, we shall at length detect the nature of this law. This method is called the inductive method of research. It was by means of it that the illustrious NEWTON detected the great law which governs the mechanism of the heavens. His induction was brief, but it was conclusive. He observed that falling bodies at the surface of the earth tend everywhere toward the centre. He observed that all such bodies falling from a state of rest fall precisely the same distance in a given interval of time, as for instance a second. He observed that the moon also falls continually toward the earth—that is, that she deviates from the tangent to her orbit every second by a space which would be a space fallen if she were not moving in an orbit. He ascertained by astronomical methods the distance of the moon, and computed the amount of this fall. Now, supposing that all these observed phenomena are due to a common cause, the question to be settled is, what is the law according to which this cause acts. The data suffice to determine this law; and when it is subsequently tested by being applied to the motions of other celestial bodies, their uniform accordance with it corroborates its truth.

THE DEDUCTIVE METHOD.

The ancients, on the other hand, pursued their inquiries after a method which may be called the deductive; that

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is to say, they began by laying down general principles, and then proceeded to deduce conclusions by logic. As we have illustrated the former method by taking the example of astronomy, the comparison may best be made by employing the same example with this. It is to be observed that what we have to account for is the celestial motions. We begin by assuming that as the celestial system is the immediate work of the author of nature, it must necessarily be perfect in all its arrangements. Hence its motions must be perfect. Now, in regard to motion, it must be noted that motion is of various kinds, as uniform, variable, rectilinear, curvilinear, zigzag, &c., &c. All these kinds of motion cannot be perfect. From the nature of things it is evident that perfect motion must be uniform and circular. Hence the motions of the heavenly bodies are uniform and circular; and thus the fundamental law of celestial mechanics is established. It differs from NEWTON'S law, and it has the misfortune of not being true; but the astronomers of Alexandria enjoyed the high satisfaction of knowing that it ought to be true, and therefore they believed it. This law, however, became to them at once a formidable obstacle in the way of astronomical progress, for it saddled them with a multitude of artificial difficulties, with which they struggled long; attaining, moreover, in the end, only a very equivocal success. Thus, taking the earth as the center of the universe, a truth which they regarded as self-evident, and observing that the planets do not, in appearance at least, move uniformly, they proceeded to build up a monstrous geometrical theory

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to reconcile facts with appearances—a theory which new observations continued constantly to falsify, and which we know now cannot, by any modification, be made to represent the truth.

Chemistry, physics, physiology, and every other branch of natural science were all darkened, befogged and shackled by similar arbitrary assumptions. Even long before the inductive method had been adopted and successfully practiced by GALILEO, KEPLER, TORRICELLI and HUYGHENS, it continued to be taught, as we find set forth in the "Margarita Philosophica" of REISCH, the compendium of the scholastic science of the sixteenth century, that four elements only enter into the composition of all material things, viz.: fire, air, earth and water; and that the palpable qualities of things are but fourteen, four primary and ten secondary, which are expressed by the words hot, cold, moist and dry, for the primary; and slippery, harsh, dense, subtle, hard, soft, rough, smooth, heavy, light, for the secondary; to which, under the name of impalpable qualities, were added colors, sounds, tastes and odors. It will easily be understood what progress chemistry could make in the attempt to reason out the composition of particular things, starting from data like these.

THE INDUCTIVE METHOD TARDILY ADOPTED.

What has thus far been said, may be true as far as it goes; and yet it does not entirely solve the original

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difficulty, but rather seems to set it backward a second step. How happens it, we may ask, that the inductive method of research, recommending itself as it does, when once explained, to the common sense of all mankind, how happens it that this method was so long in securing the recognition of philosophers as the true method of investigating nature? The solution of this new difficulty seems to be found in the following considerations. When men first began to meditate the problems presented in the universe, the questions which earliest and most deeply impressed them were those relating to the mystery of existence, to the origin of matter rather than to its properties, to the intimate essence of things rather than to their outward phenomena. It was, therefore, in the discussions of speculative philosophy that the mental habits of the earliest profound thinkers were formed; and in such discussions it seems inevitable that the form of reasoning shall be by deduction from general principles to particular conclusions. The habits formed in philosophical speculation would naturally be confirmed by the investigations of abstract mathematics, since these set out from axioms and exact definitions; and it was all but inevitable that the mathematics should precede physics in the early order of inquiry, since it is among the first necessities of civilization to require some system of mensuration of lines, surfaces and solids, and since mensuration exacts a knowledge of geometry. The tenacity with which mental habits once established maintain themselves,

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is well known. Whether the emancipation of the sciences of nature from the tyranny of such habits would have been delayed down to the sixteenth century of our era, had no eclipse come over the early culture of Greece and Italy, may be reasonably doubted; but, after the fall of the Western Empire in the fifth century, all literary and scientific progress was practically arrested for more than a thousand years. Even with the revival of letters, moreover, science scarcely began to revive before she encountered difficulties and discouragements before unknown, born of the superstition of the time—a superstition which looked upon each new discovery as something monstrous and criminal, due to Satanic agency; and menaced the discoverer with the dungeons and flames of the Inquisition.

RESULTS OF THE INDUCTIVE METHOD.

It is common to ascribe to Lord BACON the modern revolution in the methods of investigation, and the origination of the inductive philosophy. But this is hardly consistent with the fact that the inductive method had been already fully inaugurated by BRAHE, KEPLER, GALILEO, and perhaps others, many years before the publication of the "Novum Organon," which it is hardly probable that any of them ever saw. It is to be borne in mind, nevertheless, than even after the inauguration of this method, by whomsoever introduced, the advance of science could not but be, for a certain length of time,

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of necessity slow. The whole field lay before the investigators substantially unexplored, the most elementary truths in each branch of science were yet to be ascertained, the pioneers were few in number and the discouragements they met with were great. It is in the natural course of things, moreover, that investigation should be more productive of results as it is prosecuted further; and in the combination of these reasons may be found the explanation of the fact that a movement which began in the sixteenth century, almost imperceptibly, and which in the eighteenth had hardly become sufficiently marked to attract general attention, has in our time become the rush of a mighty current forming the most salient phenomenon of the civilization of the age. And as science has advanced, so industry has with equal step kept pace beside her. Each new discovery has created a new art or improved an old one; till looking through the whole extent of the industrial world, we scarcely encounter a machine, or a process, or a product, or an implement, which is not a form of applied science; and we find the laboratory and the workshop to be so intimately allied, that fully to understand either science or the arts, one must be familiar with both. In the laboratory we have the arts in embryo; in the workshop we have science in application.

INCREASE OF PRODUCTIVE POWER.

Let me conclude this part of my subject by adducing two or three examples illustrative of the practical effect

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of this association of science with industry, in the increase of productive power. And first in order, I call your attention to the manufacture of steel, an example which is entitled to be first presented, both because of the transcendent importance of this great industry, and because its wonderful development through the improvement of its processes, has taken place, as we may almost say, under our own eyes, and has gone on with a rapidity which, even in the midst of industrial wonders, is exceptional. Thirty years ago the power of this branch of metallurgy was limited to the production of masses not exceeding two or three hundred pounds in weight. Now a single Bessemer converter will produce, at each operation, six, eight, ten, or even twelve tons. By the puddling process, masses of more than forty tons have been produced. At Essen, in Prussia, a single establishment devoted to this manufacture occupies an area of four hundred and fifty acres, one-fourth of which is under cover; and in 1866 the production of steel at this establishment alone amounted to sixty-one thousand tons, exceeding the total production of the world fifteen years before.

The inventions of HARGREAVES and ARKWRIGHT for spinning cotton are now about one hundred years old. They were produced in consequence of the inadequacy of the process of spinning by hand to supply yarns for the looms then in use, all of which were hand looms. The immediate result was a great excess of supply. The looms could not consume the yarns produced, and the natural consequence which followed was the invention of

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the power loom. At present, a single operative, superintending an Arkwright machine, accomplishes the work previously done by three hundred or four hundred; and the production of woven tissues is increased in the same ratio. Of printed stuffs alone, there are manufactured in the single town of Manchester between forty and fifty millions of yards annually—enough to encircle the entire circumference of the earth. Printing was performed by hand until after the beginning of this century, some three hundred or four hundred impressions per hour being all that two men, working at a single press, could produce. The first automatic press, put in operation about 1812, increased the rapidity of production to more than one thousand per hour. Subsequent improvements carried the performance up to four thousand. In the presses thus far, the type were carried upon a horizontal bed. About thirty years ago Mr. HOE, of this city, by transferring the form to the cylinder, effected an extraordinary advance, his largest presses delivering, at need, no less than twenty thousand impressions per hour. These are impressions made on one side of the sheet only. The Bullock press, invented but five or six years ago, and shown in operation in this hall at the Exhibition of the INSTITUTE of 1870, is capable of printing on both sides of the paper, with perfect register, at one operation, and produces nearly thirty thousand impressions, or fifteen thousand sheets printed on both sides per hour. The increase of productive power over the common hand-press is in a ratio of sixty or one hundred to one. By means

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of the machine-planer for wood, the rapidity with which work is turned out is increased in the ratio of twenty or thirty to one, with a vast improvement in the accuracy of the work. With the planer for metals the gain is immeasurably greater. Similar remarks may be made of the machines for morticing and dove-tailing, and of the band-saws for the execution of scroll-work, which have attracted so much attention in our late exhibitions, and will do so in the present.

The sewing-machine is an illustration of the increase of productive power which is in every household, and its wonderful capabilities are universally known. But I need not multiply examples. To exhaust the list of available illustrations would be impossible, for it is practically inexhaustible.

AMERICA IN THE CONCOURSE OF INDUSTRIES.

In conclusion, the inquiry naturally presents itself—where are we, the industrials of the UNITED STATES, in this great concourse of nations, and what is the part which we are contributing to the march of industrial improvement? The reply, I believe, will be one of which we need not be ashamed. There is hardly an industry to the progress of which we have not largely contributed. The cotton-gin, without which the machine-spinner and the power-loom would be helpless, is American. The power-shuttle, which permits an unlimited enlargement of the breadth of the web, is American. The planing-

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machine is American. Navigation by steam is American. The mower and reaper are American. The rotary printing-presses are American. The hot-air engine is American. The sewing-machine is American. The machine manufacture of wool cards is American. The whole india-rubber industry is American. The band-saw originated, I believe, in America. The machine manufacture of horseshoes is American. The sand blast, of which the large capabilities are yet to be developed, is American. The gauge lathe is American. The only successful composing-machine for printers is American. The grain elevator is American. The artificial manufacture of ice, which you saw exhibited here two years ago under the name of the Carré process, was originally invented by Prof. ALEXANDER S. TWINING, an American. The electro-magnet was invented, and immediately after its invention was first practically applied in transmitting telegraphic signals, by Prof. JOSEPH HENRY, an American. The telegraphic instrument introduced a few years later into public use, which has since obtained universal acceptance, was invented by Prof. SAMUEL F. B. MORSE, late one of the Regents of our INSTITUTE, an American.

At the Universal Exposition of 1867, although the space allotted to our country was limited, and our industry was very inadequately represented, two things were remarkable. In the first place, the number of awards for merit made to American exhibitors was greater in proportion to the whole number of competitors than was true of any other country except France—more than

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half the exhibitors having been successful in obtaining such distinctions. Secondly, the notices of the American department of the Exposition by foreign critics were numerous, and were invariably complimentary in a very high degree. Our machines for working in metal and in wood were especially commended; and what was particularly remarked about them was their novelty and their originality. On this point the reporter of the London *Engineering* was especially emphatic. He observed that European engineers had come to regard America as 'the natural home and native land" of wood-working machinery; since the UNITED STATES had furnished the first models of the most important wood-working tools in general use in Europe, and since these tools, however modified in details, still preserve everywhere their distinctive principles and main features of construction "just as they were transmitted to us across the Atlantic." And he asserts that British and continental artisans are accustomed, whenever a new desideratum in wood-working machinery makes itself felt, to look to America to furnish the desired relief; and that they are even occasionally surprised by the appearance of a new tool from the "States" before they are aware that they want it; though they very soon learn to appreciate the value of the present after giving it a trial.

BENEFITS OF INTERNATIONAL EXPOSITIONS.

And now let me ask what must be the effect of notices like these, widely circulated throughout England and the whole continent of Europe, upon the substantial interests

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of our country? I say the substantial interests, though I am not insensible to the concomitant advantages which may be more properly called sentimental; the increased respect which such displays, and such critical judgments pronounced upon them, must secure for us an intelligent people, and a people among whom intelligence is honored; but I say the substantial interests, meaning thereby the enlargement of the demand for our productions, involving as natural consequences the increase of our foreign commerce, the growth of our manufactures, and the more rapid development of our vast natural resources still unimproved. This exposition was visited, first or last, by more than ten millions of people.* These notices were read, doubtless, by several millions. And these visitors and these readers were of every kindred and people and tongue and nation under the sun. Is it nothing to bring purchasers directly into contact with the articles they need? Is it nothing to bring industrials into the immediate presence of machines or

* Mr. CHEVALIER, editor of the official reports of the juries of the Universal Exposition of 1867, gives the following as the numbers of the persons admitted to the several successive international Expositions, beginning with that held in 1851, in London, viz:

YEAR.	PAYING VISITORS.	WHERE HELD.
1851	6,039,000	London.
1855	5,162,000	Paris.
1862	6,211,000	London.
1867	9,921,686	Paris.

In this last total are counted 5,500 season tickets, and 90,000 tickets giving admission for a week. Mr. Chevalier thinks these last may be counted equal to three admissions at least; so that the total exceeds ten millions, as stated above. To the number of visitors may very properly be added the number of exhibitors who were admitted free. This number was, in 1867, 50,226; and their assistants were more numerous than themselves. To put the total number of all who saw the Exposition at 10,000,000, is therefore a statement considerably within bounds.

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duty, by inattention, by neglect, by failure to distinguish and justly to recompense merit, by giving undue honor where merit is doubtful or wanting. These are the possible errors of a loose sense of duty. They are errors not possible, I believe, with the men who hold in their keeping at this moment the interests of the INSTITUTE, or the managers who are charged with the conduct of this FAIR. In all these gentlemen I have the highest confidence; I believe that the public have the same, as it is important that they should have. I congratulate you, therefore, gentlemen, upon the present sound and prosperous condition of your INSTITUTE, and the cheering promise it holds out of a long and brilliant career of usefulness in the future.

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